

Topic: Ion-Neutral Interactions in the Topside Ionosphere

Project Title:

Quantifying the Impact of the Neutral Atmosphere on the Topside Ionosphere During Storms

PI Name: Tim Fuller-Rowell

PI Email: tim.fuller-rowell@noaa.gov

Affiliation: University of Colorado, Boulder

Project Information:

Introduction: The primary goal of this LWS Focused Science Topic (FST) is to elucidate the photochemistry and dynamics governing ion-neutral interactions in the topside ionosphere. This proposal will elucidate the impact of the neutral atmosphere winds, temperature, composition, and the disturbance dynamo on the topside ionosphere, which contributes directly to this FST goal. Improving the ability to predict TEC changes in the topside ionosphere is critical to alleviating the disruptions to communications and navigations from geomagnetic storms. The topside ionosphere during a storm is controlled largely by electrodynamic transport from the expanded magnetospheric convective, penetration, and dynamo electric fields, together with interactions of the ions with the neutral atmosphere, which impact the topside ionospheric plasma in several ways. Equatorward neutral winds raise the plasma in altitude to a region where the O/N₂ ratio is greater, thus decreasing the plasma recombination rate. During a storm, the neutral composition changes due to Joule heating at high latitudes creating upwelling and changes in the global circulation. The new circulation changes the O/N₂ ratio, and the plasma recombination rate. Changes in the neutral H, He, and O in the topside will alter the rate of O⁺/H⁺ charge exchange and He⁺ concentration in the topside ionosphere.

Goal: Our purpose is to provide the storm-time changes in the neutral atmosphere that are important and relevant for the ion-neutral interactions in the topside ionosphere. These include the changes in neutral winds, O/N₂ ratio in the neutral composition, and the neutral hydrogen and helium profiles. The winds are particularly important at mid-latitudes where the geomagnetic field is tilted. The goal is to model the storm-time changes in the neutral species with physics-based models, compare the model estimates with observations to validate the response, and make the information available to ionospheric models. The magnetospheric energy input used to drive the model can be verified by comparing the neutral density response with observations. The changes in the neutral atmosphere following the storm that influence the topside ionosphere can be verified by comparing with mid-latitude winds from ground-based Fabry-Perot interferometers and global distribution of O/N₂ ratio from satellite airglow.

Methodology: We will use two mature physics-based models to simulate storm periods with the CTIPE and TIEGCM models when sufficient observations are available to constrain the solar and magnetospheric drivers. During those periods the physics-based models will be combined with available ground and spaced-based observations of winds and neutral composition to determine the impact on ionosphere plasma densities. The proposal will also develop forward models for the neutral atmosphere observables suitable for use in a data assimilation schemes.

Outcome: This proposal will characterize the changes in the neutral atmosphere during geomagnetic storms in order to accurately represent the important ion-neutral interaction responsible for the large changes in electron content in the F-region and topside ionosphere at low, mid, and high latitudes.

Significance: This study addresses the goals of NASA's LWS program of developing the scientific understanding needed for the United States to effectively address those aspects of Heliophysics science that may affect life and society. The proposed investigation will contribute to LWS Strategic Science Area SAA-4 to improve Physics-Based TEC Forecasting Capability. The TR&T program's objectives will be achieved in this proposal by using physics-based modeling and ground and spaced-based observations. The proposed work will contribute importantly and directly to the LWS Focused Science Topic Ion-Neutral Interactions in the Topside Ionosphere. The effort will support the NASA Heliophysics goals of understanding the Sun and its interactions with the Earth.

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